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Diving in contaminated water:

Health Risk Matrix

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Defence R&D Canada – Toronto
Technical Report
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Abstract

Water contamination can pose a serious health risk to divers of the Canadian Forces (CF) required to dive in many different environments. D Dive S tasked DRDC to develop a health risk matrix in order to help the decision makers to evaluate the risks associated with water contamination in a particular area. This report contains information about water contamination and recommendations on contamination assessment. A matrix was developed using Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998) as well as North Atlantic Treaty Organization (NATO) guidelines (NATO, 2002). The matrix also contains information on maximum environmental levels, health risks and toxicity, sources, uses and potentially contaminated areas. As the matrix is a tool for divers, a few recommendations are given for its use. A list of useful web sites is also given.

Résumé

La contamination de l'eau peut poser un risque sérieux pour la santé des plongeurs des Forces Canadiennes (FC) qui doivent travailler dans divers environnements. D Dive S a demandé à HHG de développer une matrice de risque pour la santé afin d'aider les preneurs de décision à évaluer les risques associés à la contamination de l'eau des sites de plongée. Le rapport contient des informations sur la contamination de l'eau et des recommandations sur l'évaluation de la contamination. La matrice a été développée en utilisant les Recommandations Canadiennes pour la Qualité de l'Environnement (Canadian Council of Resource and Environment Ministers, 1998) et les recommandations données par l'Organisation du Traité de l'Atlantique Nord (OTAN) (NATO, 2002). La matrice contient également des informations sur les niveaux environnementaux maximum, les risques pour la santé et la toxicité, et les sources, les usages et les endroits potentiellement contaminés. Étant donné que la matrice est un outil pour les plongeurs, plusieurs recommandations sont données sur son utilisation. Une liste de sites web utiles est également fournie.

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Executive summary

Diving in Contaminated Water: Health Risk Matrix

Quémerais, Lt(N) Bernadette; DRDC Toronto TR 2006-126; Defence R&D Canada – Toronto; October 2006.

Diving in contaminated waters can pose serious health risks especially to CF divers required to dive in waters with variable quality. As most of the time decision makers do not know about the level of contamination where divers are asked to work, Directorate Dive Safety (D Dive S, Ottawa) tasked Defence Research and Development Canada (DRDC) Toronto to develop a health risk matrix for CF divers. The matrix was developed using Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998) as well as NATO guidelines (2002).

This report discusses the various contaminants that can be found in both fresh and seawater as well as the various guidelines available for water quality. Unfortunately, water guidelines for recreational uses do not include chemical contaminants. The matrix developed contains information on maximum environmental levels, health risks and toxicity, sources, uses and potentially contaminated areas. Because the matrix is a useful tool for divers, a few recommendations are given for its use. A list of useful web sites is also included in this report.

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Diving in Contaminated Water: Health Risk Matrix

Quémerais, Lt(N) Bernadette; DRDC Toronto TR 2006-126; R & D pour la défense Canada – Toronto; Octobre 2006.

La plongée en eau contaminée peut poser un risque sérieux pour la santé, spécialement dans le cas des plongeurs des FC qui doivent plonger dans des eaux de qualité variable. Étant donné que, dans la plupart des cas, les preneurs de décision ne connaissent pas le niveau de contamination où les plongeurs doivent travailler, D Dive S (Ottawa) a demandé au groupe Health Hazards à RDDC Toronto de développer une matrice de risques pour la santé pour les plongeurs des FC. La matrice a été développée en utilisant les Recommandations Canadiennes pour la Qualité de l'Environnement (Canadian Council of Resource and Environment Ministers, 1998) ainsi que les guides de qualité de l'eau de l'OTAN (NATO, 2002).

Le rapport collige des informations sur les divers contaminants susceptibles d'être présent dans l'eau douce ou l'eau de mer ainsi que les différents critères de qualité de l'eau disponibles. Malheureusement, les recommandations de qualité de l'eau pour usage récréatif n'incluent pas les contaminants chimiques. La matrice développée contient des informations sur les niveaux environnementaux maximum, sur les risques pour la santé et sur la toxicité, sur les sources, les utilisations et les endroits potentiellement contaminés. Étant donné que cette matrice est un outil utile pour les plongeurs, quelques recommandations sont données sur son utilisation. Une liste de sites web utiles est incluse dans ce rapport.

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1 Introduction

Contaminated water has always posed a serious problem for divers. Throughout the years many divers, including Canadian Forces (CF) divers, have gotten sick as a result of exposure to contaminated water (Exercise Seahawk, 2003). With the exception of some isolated rivers, lakes and shores, most water bodies have been contaminated either by biological or chemical contaminants as a result of industrial, agricultural and urban development (Cossa *et al.*, 1998; Meybeck, 1998; Robarts, 1998). As a general rule, near-pristine waters are found where human activity is very limited, such as arctic and sub-arctic regions with very low chemical concentrations. Contaminated waters are usually found in populated areas, the northern temperate zone being the most affected area with very high chemical concentrations (Meybeck, 1998). CF divers are asked to dive in various environments all across Canada and the world. The Canadian Navy and Directorate of Dive Safety (D Dive S) are very sensitive to the fact that CF divers are exposed regularly to contaminated environments. Defence Research and Development Canada (DRDC) Toronto has been asked to look at potential problems of diving in contaminated water and develop a health risk matrix to help divers in identifying the type of equipment they should wear according to the level of water contamination (Record of decision, 2003, project 16IG03).

2 Risks and hazards

Many different types of hazards can be encountered in fresh and sea water. They vary from site to site. In the same way, the nature and extent of exposure will vary with the location (WHO, 2003; NOAA, 2004; US Navy, 2004).

As CF divers have to work in many diverse environments (fresh and seawater as well as different countries), they may be in contact with any of the contaminants described below.

The potential contaminants that can be found in waters are biological, chemical, warfare agents (chemical, biological and nuclear weapons (NBC)) and radiological contaminants.

Biological contaminants pose the biggest threat to the divers, as they are more likely to be encountered than other hazards. However, chemical contaminants can be a serious problem in some areas. Radiation is a problem only in some particular cases, such as diving in a nuclear plant. Thermal stress may occur when divers carry a warm protective equipment and also in some very particular types of dives. However, thermal stress was not accounted for in the health risk matrix, as it is mainly due to working in very warm environments. The matrix contains information on biological and chemical contaminants, including radioactive isotopes and warfare agents.

2.1 Biological hazards

According to the Guidelines for Canadian Recreational Water Quality (Health Canada, 2004), microbiological contaminants are the main problem in Canadian waters. Biological contamination will vary from location to location in relation to the density of population, the level of industrialization as well as the climate.

2.1.1 Fecal contamination

Fecal pollution can lead to serious health problems due to the presence of infectious organisms. Fecal pollution is mainly due to the presence in water of raw human sewage and/or animal manure (WHO, 2003). Fecal pollution is generally more important in areas heavily populated, particularly in developing countries where sanitation is limited or non-existent, in agricultural areas with high livestock density, and in recreational waters heavily used (i.e., in popular beaches) (WHO, 2003).

Fecal contamination includes bacteria (*Escherichia coli*, *Campylobacter* spp., viruses (Polioviruses, Hepatitis A), parasitic protozoa (*Cryptosporidium parvum*, *Giardia lamblia*) and helminths (*Ascaris*) (WHO, 2003).

Health problems associated with fecal contamination are gastroenteritis, diarrhoea and vomiting, respiratory diseases, hepatitis, dysentery, anaemia, poliomyelitis and ascariasis (WHO, 2003). According to WHO (2003), various studies have reported a does-response relationship between fecal contamination and 1) enteric illness and 2) acute febrile respiratory illness (AFRI), although contacting AFRI has generally a lower probability than contacting enteric illness.

Divers using regular diving gear (scuba divers) are exposed to fecal contamination as microorganisms may enter the body through the nose, the ears, the mouth and open wounds, because the wet suit does not protect the skin (NOAA, 2004; US Navy, 2004). The diver may also inhale water through the regulator as it creates small droplets of water (NOAA, 2004; US Navy, 2004).

2.1.2 Free-living organisms

In addition to fecal contamination, other pathogenic organisms freely exist in open waters. They may be indigenous to an area, or have been introduced, and then have colonized the area (WHO, 2003).

***Vibrio* species**

Many studies have shown that *Vibrio* species are naturally present in marine environments, in both temperate and tropical waters (WHO, 2003). Infections due to *Vibrio* species are both intestinal and extraintestinal (infection of open wounds). In the case of intestinal diseases, it seems that a large number of organisms have to be ingested to get the disease, which is unlikely to occur during diving activities (WHO, 2003).

***Aeromonas* species**

These are considered to be ubiquitous in both fresh and marine waters, with high numbers occurring during the warmer months of the year (WHO, 2003). These species play a role in enteric illnesses, although they are generally self-limited. Children and immuno-compromised adults are more affected by the organisms (WHO, 2003).

Free-living amoebae

These are common to soil and aquatic environments (WHO, 2003). They can cause serious illnesses often with fatal consequences. Diseases include encephalitis, keratitis, and meningoencephalitis (WHO, 2003).

***Leptospira* species**

These are motile bacteria and are ubiquitous in the environment. The pathogenic species normally live in the kidney of animal hosts but people can be affected by contact with freshwater or soil (WHO, 2003). The bacteria enter the body through open wounds and through the mucosal surfaces of the mouth, nose and conjunctiva. The bacteria cause the disease called leptospirosis. Symptoms may vary from mild flu-like illness to a severe form including kidney failure and haemorrhage. The severe form can be fatal (WHO, 2003).

As for fecal contamination, regular diving gear does not protect against these organisms, therefore it is important for divers to be protected even when diving in moderately contaminated waters (NOOA, 2004; US Navy, 2004).

2.1.3 Algae and cyanobacteria

Although they might not be seen as a health risk, algae and cyanobacteria may produce toxins poisonous to the human being. Algae can be found in the range of a single cell form to that of seaweed (WHO, 2003). Cyanobacteria are organisms having characteristics of bacteria as well as those of algae. They are similar to unicellular algae and can perform photosynthesis as they contain blue-green or green pigments (WHO, 2003). Algal blooms are a frequent phenomena in fresh and sea waters around the world. They have increased in recent decades (WHO, 2003), and therefore, they are a potential risk for CF divers, who dive in many diverse environments.

Marine waters

Health risks associated with the presence of algae or cyanobacteria occur through skin contact, ingestion or inhalation. Cyanobacteria have been associated with acute dermatitis and skin burning (WHO, 2003). *Nodularia spumigena* is a cyanobacterium known to cause hepatotoxicity in animals. Even if it was never reported toxic for humans, WHO (2003) suggested that ingesting high amounts of the toxin could cause adverse effects. Inhalation of marine algae (dinoflagellates) causes severe irritation of conjunctiva and mucus membranes, followed by coughing, sneezing and tingling of the lips (WHO, 2003).

Freshwaters

Cyanobacteria living in freshwaters produce three types of toxins: microcystins, neurotoxins and cytotoxins. Microcystins are the most frequent toxins found in freshwaters. They cause severe liver damages and the main exposure route is through inhalation (WHO, 2003). Toxicity can be either acute or chronic and repeated exposure to the toxin may also lead to liver damage (WHO, 2003). Health effects associated with neurotoxins are suffocation, cramps, tremor, diarrhoea, vomiting and paralysis. Although neurotoxins are extremely toxic and potentially lethal, it is believed that concentrations in freshwaters are not high enough to cause death, and recovery after ingested sublethal doses seems to be complete (WHO, 2003). Cytotoxins cause kidney and liver failures. Other symptoms such as injury to the lungs, adrenals and intestines have also been reported (WHO, 2003).

Divers using regular diving gear can be exposed to these toxins through ingestion, skin contact and inhalation.

2.2 Chemical hazards

According to the US Navy (2004), more than 5,000,000 chemicals are presently in commercial use worldwide. These chemicals can be divided into two groups: organic and inorganic contaminants. According to the WHO (2003), the use of wet suits allows for long periods in the water. In addition, the water is trapped between the wet suit and the skin, creating a micro-environment that will enhance the absorption of chemicals through the skin (WHO, 2003). However, the potential risk associated with toxic chemicals is smaller than the risks associated with microorganisms (WHO, 2003) and Health Canada (2004) considers that toxic chemicals are not in concentrations high enough to cause health effects in Canadian waters. However, there are exceptions and it is important to know if the water is contaminated with chemicals before diving.

2.2.1 Organic contaminants

They are many organic contaminants present in fresh and sea waters due to agricultural and industrial activities. Some of these substances are not soluble and will accumulate in particles while others are soluble and will remain in the water column (WHO, 2003).

Organochlorine pesticides and polychlorinated biphenyls (PCBs)

These compounds are extremely toxic and also very stable, which make them very persistent in the environment. Contaminants such as PCBs are suspected to be carcinogenic and Dichloro Diphenyl Trichloroethane (DDT) is known to have an effect on reproductive organs (linked to sterility). However, they are not soluble and, thus, will accumulate on particles (US Navy, 2004). They are more of a concern when working in sediments as some areas might have been heavily contaminated (WHO, 2003).

Other pesticides

Numerous pesticides are now available on the market. Amongst them, atrazine and its metabolites (used as a corn herbicide), organophosphates and carbamates (neurotoxic pesticides), and glyphosate (herbicide known as Roundup) are the ones most frequently found. These pesticides are less persistent in the environment and it is unlikely that concentrations in open waters will be high enough to cause a risk to divers. Nevertheless, pesticides such as glyphosate and atrazine are soluble, widely used, and may be in high concentrations in some areas.

Hydrocarbons

Hydrocarbons are composed of atoms of carbon and hydrogen. They can be in the form of small volatile molecules (natural gas) or in the form of large heavy molecules (coal). Solvent, oil, fuel and polycyclic aromatic hydrocarbons (PAHs) are all hydrocarbons. PAHs are heavy molecules capable to evaporate and to dissolve in water (US Navy, 2004). Volatile organic compounds (VOCs) are generally hydrocarbons that are volatile. They include solvents but also the lightest PAHs. VOCs should not be a concern in water as they have a tendency to evaporate from the water column. Creosote is a petroleum derivative used as a wood preservative. It is know to be carcinogenic and new piling, dock supports, etc. may be a risk for divers (US Navy, 2004). In addition, neoprene can be damaged by some of the hydrocarbons, therefore, neoprene diving suits are not recommended when diving in areas likely to have high concentrations of hydrocarbons such as in petroleum spills (NOAA, 2004; US Navy, 2004).

NOAA (2004) gives a list of contaminants that are so dangerous that no divers should work around them, although they do not give the concentrations at which these chemicals are really hazardous:

- - Acetic anhydride
- - Acrylonitrile
- - Carbon tetrachloride
- - Cresol
- - Chlordane

- - Dichloropropane
- - Epichlorohydrin
- - Ethylbenzene
- - Methyl chloride
- - Methyl parathion
- - Perchloroethylene
- - Styrene
- - Trichloroethylene
- - Xylene

2.2.2 Inorganic contaminants

The most toxic inorganic contaminants are heavy metals although other contaminants such as nitrite, nitrate, cyanide, and fluoride may cause health effects if they are present in high concentrations. Some of the metals are insoluble (mercury, lead) and are associated with particles. Therefore they will be a concern if working with sediments. It is also the case for tributyltin (TBT) which is widely used in anti-fouling paint (NOAA, 2004). According to NOAA (2004), TBT is a very toxic compound which is commonly found in the bottom of harbours. Although the WHO (2003) states that inorganic contaminants are a risk only if they are ingested, NOAA (2004) considers that working with sediments may cause a risk, particularly if they are contaminated with TBT. CF divers may dive in Esquimalt and Halifax harbours and may also perform repairs on ships' body. Therefore, they are likely to be exposed to TBT.

2.3 Chemical/biological warfare agents

According to the US Navy (2004), chemical/biological warfare agents pose an extreme hazard to the divers and every effort should be made to identify the agent and to mitigate the concentration or exposure prior to diving.

2.4 Radiological hazards

Radiological contaminants may enter the environment through accidents/spills (NOAA, 2004). Divers may also have to work in the fuel pool of nuclear reactors (US Navy, 2004). To protect the divers, diving time should be reduced in order to reduce the length of exposure and proper shielding should be used (NOAA, 2004). Ionizing radiation is known to be carcinogenic so any precaution should be taken to avoid/limit exposure.

3 Guidelines for water quality

The Canadian Council of Resource and Environment Ministers (CCREM) has various guidelines regarding water quality (Canadian Council of Resource and Environment Ministers, 1998). Some of them concern the health of the ecosystem. Only two of them concern human health and they are developed by Health Canada. One of the guidelines has been developed for drinking water. This guideline was developed considering exposure through ingestion only, and for an amount of water ingested of 1.5 L per day (Health Canada, 2004). This guideline is not appropriate for CF divers as it considers only exposure through ingestion and for a larger amount of water that would not be normally ingested by a diver. The other guideline was developed for recreational use of the water.

According to WHO (2003), recreational uses of water include a large variety of activities, some of them involve whole-body water contact and some of them involve non-contact activities. The first range of activities includes swimming, surfing (wind-surfing), waterskiing, slalom canoeing and diving. The second range includes fishing, picknicking, sailing, walking and birdwatching (WHO, 2003). Due to the large range of activities that these guidelines cover, they were developed for all types of exposure (i.e., contact, ingestion and inhalation), and are not dependant on the length of exposure. These guidelines were developed using epidemiological data on waterborne diseases available in the literature (WHO, 2003; Health Canada, 2004). Therefore, recreational water quality guidelines are appropriate to be used by CF divers.

They are quite few guidelines for recreational water quality. Most of them are for biological contaminants as they are the main concern for recreational activities. Water quality guidelines for recreational waters can be found at Health Canada (2004), US EPA (2003) and WHO (2003). This section of the report only describes the available guidelines. Exposure assessment and need for developing guidelines are discussed in the following sections.

3.1 Biological contaminants

Fecal contamination

In regards to fecal contamination, all agencies differentiate between freshwater and seawater. Both *Escherichia coli* and *enterococci* can be used as indicators of water quality in freshwaters, but only *enterococci* are an indicator in marine waters. The recommended guidelines are shown in Table 1. The guidelines are quite similar for the three agencies.

Table 1Guidelines for fecal contamination in fresh and marine waters (Health Canada, 2004; US EPA, 2003; WHO, 2003)

		Health Canada (2004)	US EPA (2003)	WHO (2003)
Freshwater	*Escherichia coli*	200/100 mL	126/100 mL	
	Enterococci	35/100 mL	33/100 mL	≤ 40/100mL
Seawater	*Enterococci*		35/100 mL	≤ 40/100mL

Other contaminants

There are no guidelines available for other biological contaminants such as free living organisms, cyanobacteria and algae in any of the agencies.

Health Canada (2004) considers that fecal coliforms are a good indicator of bacterial contamination as they are in the intestines of many warm-blooded animals in numbers a lot greater than pathogens. However, Health Canada (2004) recommends that *Pseudomonas aeruginosa* be used as an indicator of pathogens is necessary. For most of the pathogens, Health Canada (2004) recommends that testing be performed only if there is any epidemiological evidence of the presence of the pathogens in the water.

According to Health Canada (2004), fecal contamination is not an indicator of the presence of protozoa. However, they do not recommend routine monitoring of waters for these organisms. They only recommend investigating waterborne outbreaks (Health Canada, 2004).

Health Canada (2004) recommends not to go into waters containing blue-green algal blooms; they recommend testing for toxic phytoplankton only for epidemiological investigations (Health Canada, 2004).

3.2 Chemical contaminants

Health Canada considers that chemical contamination is not a problem in Canadian waters. Therefore, there are no guidelines for chemical contaminants in recreational waters (Health Canada, 2004). WHO (2003) recommends that 10 times the concentration of the drinking water guidelines be used as users may ingest up to 200 mL of water per day (drinking water guidelines

are based on ingestion of 1.5 to 2 L of water per day depending upon the guideline) (Health Canada, 2004; WHO, 2003).

3.3 Warfare agents

There are no guidelines for warfare agents for recreational waters although NATO has a guideline for drinking water (NATO, 2002). The concentration of the drinking water guidelines could be multiplied by ten to have a recreational water guideline (WHO, 2003) although some agents act through skin exposure therefore using 10 times concentration of the drinking water guidelines might not be appropriate.

3.4 Radiological contaminants

There are no guidelines for radiological contaminants. All agencies have guidelines for drinking water although in this case exposure by contact is as important as exposure through ingestion. It is therefore not recommended to use 10 times the concentration of the drinking water guidelines.

4 Exposure assessment/diving scenarios

Guidelines do not exist for most of the contaminants, which makes environmental assessment quite difficult to perform. Developing guidelines is a possibility, however, it will be useful only if testing is available for all of the contaminants and if it is possible to perform an accurate assessment of the diving area.

Divers are very mobile in the water. They may be in contact with different water masses; they may have to work with sediments, close to ships or docks where contamination will be very different from the water column. In addition, as there are many types of contaminants (up to 5,000,000 of chemicals presently available on the market), it is impossible to test for all of them (US Navy, 2004). Furthermore, testing requires a few days to get analytical results as direct reading instruments are not available for most of the contaminants present in the water.

Therefore, assessing chemical contamination properly will require performing a thorough evaluation of the diving site way before diving activities occur, which will not be possible in deployment sites or in a case of emergency. Furthermore, it will be impossible to test for all the contaminants present in the environment.

When possible, it is recommended that a thorough environmental assessment of the diving sites be performed (i.e. on areas used for regular diving exercises). However, as it is not possible in most of the cases it is then extremely important to be able to evaluate contamination on a qualitative basis. The US Navy (2004) uses four categories for water quality qualitative assessments for diving purposes:

Category 1 (US Navy, 2004)

It corresponds to gross visible contamination with biological or chemical contaminants. Examples are fuel spills, visible raw sewage and human remains recovery.

Category 2 (US Navy, 2004)

This category corresponds to moderate contamination of either biological or chemical contaminants.

Category 3 (US Navy, 2004)

Baseline contamination means that the water quality is as normally expected with no obvious contamination and has not shown to cause acute effects on divers.

Category 4 (US Navy, 2004)

This category corresponds to pristine waters far from any direct source of contamination. It includes offshore, drinking water reservoirs, swimming pools and remote locations.

Although Categories 1 and 4 may be easy to determine, Categories 2 and 3 may be more difficult to evaluate. The US Navy (2004) proposes diving scenarios that can be used to assess water quality.

4.1 After rainfall

After rainfall, contaminants that have been accumulated in soils can be washed out into a watershed basin and therefore contaminate the water. According to the US Navy (2004), dives planned immediately or a few days after a large rainfall should consider a variety of exposure to chemical and biological hazards (US Navy, 2004).

4.2 Working in sediments

As seen in the previous section, most chemicals are insoluble and tend to accumulate in sediments. On the other hand, it has been shown that microorganisms are also in higher concentrations in sediments. Therefore, all precautions should be taken when diving and working with sediments (US Navy, 2004).

4.3 Points of discharge

Contamination may be sometimes quite obvious when there is a point of discharge such as discharge points for industrial or municipal effluent. These effluents can have high levels of both chemicals and microorganisms, and every precaution should be taken when diving close to these areas (US Navy, 2004).

4.4 Working with hazards

Divers may have to work in areas where known chemicals are present. For example, fuel contamination may be present if there is a leaking vessel or in case of aircraft recovery. If working with flooded wood material, contamination with creosote should be suspected, and contamination with TBT should be suspected when working with anti-fouling paint (US Navy, 2004). Harbours such as Esquimalt and Halifax should be considered as hazardous environments as fuel may spill from the ships, because of the presence of TBT due to antifouling paint (NOAA, 2004) and due to the presence of creosote on immersed wood (NOAA, 2004). When working on wrecks, divers should pay attention to possible chemicals leaking from the wreck.

4.5 Algal blooms

Algae pose a serious health hazards not only to divers but also to surface personnel. Protective gear should be used when diving in areas where algal blooms are present US Navy, 2004).

4.6 Human remains recovery

In recovering human remains, biological contamination can be important and all divers should be well protected. Skin and mucous membranes should not be in contact with remains or with water in the vicinity of the remains. Divers should also ensure that they wear protective gloves to minimize introduction of potentially harmful materials to their hands (US Navy, 2004).

5 The health risk matrix

The health risk matrix has been developed to help divers estimate what type of contamination can be present in the water they are going to dive in. This should allow them to decide the type of protective equipment they should dive with.

The health risk matrix includes Canadian and American recreational guidelines, Canadian and NATO drinking water guidelines, environmental levels, health risks, and sources/uses/contaminated areas for each parameter.

The health risk matrix is presented Annex A.

5.1 Parameters

Unfortunately, as there are thousands of potential contaminants that can be present in contaminated water, it was essential to determine a list of priority contaminants before developing the matrix.

The Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998) regroups a list of parameters of concern. Most of these contaminants are widely found in the environment and some of them are very toxic even at low levels. NATO (2002) has guidelines for Nuclear, Biological and Chemical (NBC) agents.

The parameters included in the matrix are based on the list of parameters given in both Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1987) and NATO (2002).

Although there are no guidelines for viruses and protozoa, they were included in the matrix. As it is a very toxic pesticide, lindane was also included. Even though their use is prohibited or very limited in North America, PCBs and DDT where included in the matrix. They maybe used in developing countries and are extremely toxic. However, as for lindane there are no water quality guidelines for these compounds.

However, many other contaminants exist. An extensive list of parameters and guidelines are presented in the Environment Canada web site (see Annex B).

5.2 Criteria

The initial plan was to develop *a matrix outlining criteria to distinguish moderately contaminated water (MCW) to that of highly contaminated waters (HCW)* (Record of decision, 2003). In the literature, there are no criteria available to distinguish moderately contaminated water from highly contaminated water. The distinction between non-contaminated to contaminated water is subjective and depends upon the water use. An environmentalist working on the protection of aquatic life will consider water as contaminated at lower levels than will a professional from Health Canada working on recreational uses.

As seen in the previous section, WHO (2003) recommends to use 10 times the concentration of the drinking water guidelines when guidelines for recreational use are not available.

5.3 Environmental levels

Environmental levels were found in the literature (Cossa et al., 1998; Quémerais et al., 1998; CCME, 1998; Meybeck, 1998) and on the International Program on Chemical Safety (IPCS) web site (see Annex B). As some data have been compiled many years ago, it is possible that some values may not be accurate or up-to-date. However, they are a good indication of what can be expected in the environment. Only the maximum environmental level has been recorded in the matrix. In some cases, the maximum value is lower than the drinking water guideline, meaning that the risk associated with that parameter is really low (for example, copper and mercury). However, divers have to keep in mind that they may encounter higher levels if they dive in special areas (areas severely affected by mining activities in the case of copper and mercury).

As research and monitoring for water quality is an on-going activity, the matrix should be revised regularly in terms of environmental levels.

5.4 Health risks

Health risks associated with each parameter have been included. Toxicity on each parameter was found on the extension Toxicology Network, the U.S. Environmental Protection Agency and on the IPCS web sites (see Annex B). More toxicity information can be found as well in the Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998).

5.5 Sources, uses and potentially contaminated areas

The matrix compiles information concerning production, use and/or potentially contaminated areas for each parameter. Users have to remember that inorganic contaminants and some organic contaminants such as PAHs are of natural origin and that they will be found everywhere. However, concentration levels may be a lot higher than natural concentrations in some cases.

The last column of the matrix can help divers to estimate what type of contamination they may find. For example, waters affected by smelting industries and mining activities are more likely to be highly contaminated in some inorganic parameters. In the case of pesticides, streams close to intense agricultural activity have to be consider as contaminated. Urban areas, harbours with intense ship activity and industrial areas have to be considered as contaminated as well.

6 Recommendations

Although they may think they are protected by their wet suits, divers may be at greater risk than recreational swimmers as they are totally immersed. Divers can be exposed through contact with mucous membranes (ears, nose, and mouth) and through ingestion. Scuba divers are at particular risk as they may also inhale droplets of water through their regulator (NOAA, 2004; US Navy, 2004). In addition, the wet suit does not protect the diver's skin from exposure and it readily absorbs water, which makes it very difficult to decontaminate it (NOAA, 2004; US Navy, 2004). The wet suit also creates a micro-environment which may enhance the contact between chemical contaminants and the skin (WHO, 2003). Moreover, some chemicals may degrade the neoprene of the wet suit (NOAA, 2004; US Navy, 2004).

Unfortunately, there are too many contaminants to be able to assess accurately for all of them, and guidelines don't exist for most of them. Furthermore, performing a thorough and accurate environmental assessment of a diving site is complex in terms of sampling and analytical protocols, and it requires a long time to do it. Such an evaluation can be performed in regular diving sites used for exercises in Canada; however, environmental assessments are not feasible in deployments or in case of emergency. Even though new guidelines will be developed, they will not be useful if an accurate evaluation of the diving site is not performed.

Therefore, evaluation of contamination should be a risk assessment based on the particular situation of the diving area (existence of point of discharge, high levels of particles in the water, obvious contamination, working with sediments, wrecks, presence of immersed wood, human remains recovery) (US Navy, 2004). This risk assessment will have to be performed on site by the divers themselves.

A review of the protective equipment that can be used is available in Barsky (1999), NOAA (2004) and the US Navy (2004). The latter also recommend four levels of protection according to the four water quality categories (see Section 4 herein). Protocols for the decontamination of the equipment are available in US Navy (2004) and NOAA (2004).

The following are recommended:

- When divers use regularly the same location (i.e. for exercise purposes), it is recommended that a thorough environmental assessment be performed for that area. The health risk matrix can help determine which contaminants should be investigated and should help interpret the data.
- As guidelines exist for bacteriological contaminants, it is recommended to perform a bacterial analysis for the diving site whenever possible.
- A policy for diving in contaminated waters should be developed. The policy should include information about waterborne diseases and how to perform an accurate risk assessment of the diving site. As recommended by the US Navy (2004), diving scenarios can be used to assess water quality and perform a risk assessment when analysis is not possible.

- CF divers should be properly trained on the procedures to follow when diving in contaminated waters. These procedures should include how to perform a risk assessment, the proper equipment to use as well as the decontamination procedures.
- CF divers should use the list of web sites provided in Annex B prior to diving to determine if contamination exist in the diving area.
- As a rule of thumb, where there is a doubt on the quality of the water in the diving area, protective equipment should be always used.

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Annex A Health Risk Matrix

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
Microbiological							
Fecal coliforms/E. Coli	200/100 mL	126/100 mL	No presence	No presence	up to >103/100 mL	Gastro-intestinal diseases, skin irritation and hear infections	Freshwaters, in areas directly impacted by sewage discharges
Enterococci	35/100 mL	33/100 mL			up to >35/100 mL	Gastro-intestinal diseases	Mostly marine waters in areas directly impacted by sewage discharges
Viruses						Gastroenteritis, Hepatitis A and E, fever, respiratory ailments, eye infections…	Pollution by animal waste, municipal sewage,
Protozoa						Diarrhea, meningoencephalitis, schistosomiasis and dermatatis	any source of human waste Any aquatic environment
Physical							
pH	6.5 to 8.5		6.5 to 8.5	5 to 9	N/A	Eye irritation	
Turbidity	50 NTU		1	1	N/A	Underwater hazards	
Clarity	Secchi 1.2 m				N/A	Underwater hazards	
Chemical							
Major ions							
Barium			1.0 mg/L		< 15,000 µg/L	Gastro-intestinal disturbances, muscular	Release primarily from copper smelting industries

						weakness, high blood pressure	
Boron			5 mg/L		< 4.5 mg/L	Respiratory irritation, eye and nasal irritation, dermatitis	Mainly mining activities and natural sources
Bromate			0.01 mg/L			Damage to kidneys	Municipal sewage
Chloride			250 mg/L	600 mg/L	< 861 mg/L	Throat and eye irritation	Volcanic activities, electrolysis of chloride salts, combustion of fuel and waste disposal
Fluoride			1.5 mg/L		< 2800 mg/L	Lung and bladder cancer, dental fluorisis	Weathering and dissolution of minerals, emissions from volcanoes and in marine aerosols, phosphate ore production and use, aluminium manufacture
Iron			0.3 mg/L		< 90 mg/L	Vomiting and diarrhea, liver cancer	Very common in environment
Magnesium				100 mg/L	< 1,000 mg/L	Depression, muscle weakness, fatigue, sleepiness	Very common in environment
Nitrate			45 mg/L		< 450 mg/L	Methaemoglobinaemia but risk very low in adults	Commercial nitrogenous fertilizers
Sodium			200 mg/L		< 130 mg/L	Can causes various cells of the body, including those of the brain, to shrink (drinking seawater)	Very common in environment
Sulfate			500 mg/L	300 mg/L	< 3,040 mg/L	Intestinal problems	Minerals and natural gases, use of fossil fuel in refineries, pulp and paper industries, power plants
Sulphide (as H2S)			0.05 mg/L		< 14 ng/L	If inhaled, respiratory problems	Minerals and natural gases, use of fossil fuel in refineries, pulp and paper industries, power plants

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
Heavy metals							
Aluminum			0.1 mg/L		< 65 mg/L	Nausea, vomiting, diarrhoea, mouth ulcers, skin ulcers, skin rashes and arthritic pain	Mining and agriculture, and coal combustion
Antimony			0.006 mg/L		< 9.1 mg/L	Nausea, vomiting and diarrhea	Industrial dust, auto exhaust and home heating oil
Arsenic			0.025 mg/L	0.3 mg/L	< 280 mg/L	Skin cancer	Mining, agriculture and forestry
Cadmium			0.005 mg/L		< 166 ng/L	Nausea, vomiting, diarrhea, muscle cramps, salivation, sensory disturbances, liver injury, convulsions, shock and renal failure	Metal plating and coating operations, nickel-cadmium and solar batteries and in pigments
Chromium			0.05 mg/L		< 215 µg/L	Damage to liver, kidney circulatory and nerve tissues; skin irritation	Stainless steel, protective coatings on metal, magnetic tapes, and pigments for paints, cement, paper, rubber, composition floor covering and other materials. Its soluble forms are used in wood preservatives
Copper			1 mg/L		< 600 µg/L	Gastrointestinal disturbance, including nausea and vomiting; liver or kidney damage	Household plumbing materials
Lead			0.01 mg/L		< 100 µg/L	Kidney problems or high blood pressure	Alkyllead fuel additives
Manganese			0.05 mg/L		< 2.8 mg/L	Neurological problems	Manufacture of alloys, steel, iron products; mining
Mercury			0.001 mg/L		< 10 ng/L	Kidney and brain damage	Dry-cell batteries, fluorescent light bulbs, switches,

							and other control equipment, silver and gold mining, dental amalgams
Selenium			0.01 mg/L		< 330 µg/L	Hair and fingernail changes; damage to the peripheral nervous system; fatigue and irritability; damage to kidney and liver tissue, and the circulatory system	Electronic and photocopier components, glass, pigments, rubber, metal alloys, textiles, petroleum, medical therapeutic agents, and photographic emulsions
Uranium			0.02 mg/L		< 0.003 mg/L	Lung cancer	Mining
Zinc			5 mg/L		< 3.0 mg/L	Gastrointestinal distress, nausea and diarrhoea	Mining, zinc production facilities, iron and steel production, corrosion of galvanized structures, coal and fuel combustion, waste disposal and incineration , the use of zinc-containing fertilizers and pesticides
Other inorganic contaminants							
Cyanide			0.2 mg/L	6 mg/L	< 0.37 mg/L	Rapid breathing, tremor, weight loss, thyroid effects, nerve damage	Use to make nylon and other synthetic fibers and resins, as herbicides.
Nitrilotriacetic acid			0.4 mg/L		< 3.9 mg/L	Carcinogen, kidney toxicant	Pesticide
Chloramines (total)			3 mg/L			Symptoms of asthma, eyes and nose irritation, stomach discomfort, anemia	Microbiocide
Organochlorine pesticides							
Aldrin + diedrin			0.0007 mg/l		< 40 ng/L	Liver problems	Insecticides

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
DDT					< 66 ng/L	Main effect is on the nervous system: hyperexcitability, tremor, ataxia, and finally epileptiform convulsions	Insecticide
Methoxychlor			0.9 mg/L		< 12 ng/L	Central nervous system depression, diarrhea, and damage to liver, kidney and heart tissue, retards growth	Insecticide
Lindane				0.6 mg/L	< 600 ng/L	High body temperature and pulmonary edema, liver and kidney damage	Insecticide
Organophosphorus pesticides							
Azinphos-methyl *(Gluthion)*			0.02 mg/L		< 0.5 µg/L	Can impair concentration and memory, and cause headache, irritability, nausea, vomiting, muscle cramps, and dizziness,	Insecticide
Chlorpyrifos			0.09 mg/L			May affect the central nervous system, the cardiovascular system, and the respiratory system, also a skin and eye irritant	Insecticide
Diazinon			0.02 mg/L		< 0.2 µg/L	Weakness, headaches, tightness in the chest, blurred vision, nonreactive pinpoint pupils,	Insecticide

						salivation, sweating, nausea, vomiting, diarrhea, abdominal cramps, and slurred speech	
Dimethoate			0.02 mg/L		< 4.0 µg/L	Numbness, tingling sensations, incoordination, headache, dizziness, tremor, nausea, abdominal cramps, sweating, blurred vision, difficulty breathing or respiratory depression, and slow heartbeat	Insecticide
Glyphosate			0.28 mg/L		< 1,700 µg/L	congestion of the lungs; increased breathing rate, kidney damage, reproductive effect	Herbicide
Malathion			0.19 mg/L		< 50 ng/L	Numbness, tingling sensations, incoordination, headache, dizziness, tremor, nausea, abdominal cramps, sweating, blurred vision, difficulty breathing or respiratory depression, and slow heartbeat	Insecticide
Parathion			0.05 mg/L		< 0.01 µg/L	Pallor, nausea, vomiting, diarrhea, abdominal cramps, headache, dizziness, eye pain, blurred vision, constriction or dilation of the eye pupils, tears, salivation, sweating, and confusion	Insecticide
Phorate			0.002 mg/L			Numbness, tingling sensations, incoordination, headache, dizziness, tremor, nausea, abdominal cramps, sweating, blurred vision, difficulty breathing or respiratory depression,	Insecticide

						and slow heartbeat	
Terbufos			0.001 mg/L			Nausea, abdominal cramps, vomiting, salivation, excessive sweating, and diarrhea	Insecticide

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
Carbamates (pesticides)							
Aldicarb			0.009 mg/L		< 500µg/L	Weakness, blurred vision, headache, nausea, tearing, sweating, and tremors	Insecticide
Bendiocarb			0.04 mg/L			Weakness, blurred vision, headache, nausea, abdominal cramps, chest discomfort, constriction of pupils, sweating, muscle tremors, and decreased pulse	Insecticide
Carbaryl			0.09 mg/L		< 300 µg/L	Nausea, stomach cramps, diarrhea, and excessive salivation	Insecticide
Carbofuran			0.09 mg/L			Nausea, vomiting, abdominal cramps, sweating, diarrhea, excessive salivation, weakness, imbalance, blurring of vision, breathing difficulty, increased blood pressure, and incontinence	Insecticide
Triazine (pesticides)							
Atrazine + metabolites			0.005 mg/L		< 4,300 ng/L	Abdominal pain, diarrhea and vomiting, eye irritation, irritation of mucous membranes, and skin reactions	Herbicide
Cyanazine			0.01 mg/L		< 1,400 ng/L	Inactivity and depression	Herbicide

Metribuzin			0.08 mg/L		Labored breathing	Herbicide
Simazine			0.01 mg/L	< 610 ng/L	Weight loss, changes in blood, damage to testes, kidneys, liver and thyroid, gene mutations, cancer	Herbicide
Chlorophenols						
Dichlorophenol 2,4			0.9 mg/L	< 24 µg/L		Chlorination of water
Pentachlorophenol			0.06 mg/L	< 10,500 µg/L	Damage to the central nervous system, reproductive effects and damage to liver and kidneys, cancer	Fungicide and wood preservative
Tetrachlorophenol 2,3,4,6			0.1 mg/L	< 8,270 µg/L	Depressed activiy and motor weakness	Fungicide and wood preservative
Trichlorophenol 2,4,6			0.005 mg/L	< 115 µg/L	Decreased activity and motor weakness	Antiseptics and disinfectants
Other pesticides						
Bromoxynil			0.005 mg/L	< 0.1 µg/L	Weight loss, fever, vomiting, headache, and urinary problems	Herbicide
Dicamba			0.12 mg/L	< 0.5 µg/L	Anorexia, vomiting, muscle weakness, slowed heart rate, shortness of breath, central nervous system effects	Herbicide
Dichlorophenoxyacetic acid 2,4			0.1 mg/L	< 21.6 µg/L		Herbicide
Dinoseb			0.01 mg/L	< 44 µg/L	Fatigue, thirst, sweating, insomnia, weight loss, headache, flushing of the face, nausea, abdominal pain, and occasional diarrhea	Herbicide
Diquat			0.07 mg/L	< 1 mg/L	Dehydration, cataract	Herbicide
Diuron			0.15 mg/L			Herbicide

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
Metolachlor			0.05 mg/L		< 2,900 ng/L	Abdominal cramps, anemia, shortness of breath, dark urine, convulsions, diarrhea, jaundice, eakness, nausea, sweating, and dizziness	Herbicide
Paraquat			0.01 mg/L		< 1 mg/L	Abdominal pain, loss of appetite, nausea, vomiting, and diarrhea, thirst, shortness of breath, rapid heart rate, kidney failure, lung sores, and liver injury	Herbicide
Picloram			0.19 mg/L			Damage to central nervous system and liver, weakness, diarrhea, weight loss	Herbicide
Trifluralin			0.045 mg/L		< 41 µg/L		Herbicide
Volatile organic compounds							
Benzene			0.005 mg/L		< 330 µg/L	Temporary nervous system disorders, immune system depression, anemia, chromosome aberrations, cancer	Building block for making plastics, rubber, resins and synthetic fabrics like nylon and polyester, solvent in printing, paints, dry cleaning
Carbon tetrachloride			0.005 mg/L		< 1,500 µg/L	Liver, kidney and lung damage, cancer	Chlorofluorocarbon propellants and refrigerants, dry cleaning agent & fire extinguisher, in making nylon, as a solvent for rubber cement, soaps, insecticides
Dichlorobenzene			0.2 mg/L		< 860 µg/L	Damage to the nervous	Chemical intermediate for

1,2						system, liver, kidneys and blood cells	making agricultural chemicals, primarily herbicides, solvent for waxes, gums, resins, wood preservatives, paints, insecticide for termites and borers, in making dyes, as a coolant, deodorizer, degreaser
Dichlorobenzene 1,4			0.005 mg/L		< 410 µg/L	Nausea, vomiting, headaches, and irritation of the eyes and respiratory tract, anemia, skin lesions, appetite loss, damage to liver and changes in blood	Insecticidal fumigant against clothes moths, deodorant for garbage and restrooms, insecticide and fungicide on crops, in the manufacture of other organic chemicals and in plastics, dyes, pharmaceuticals
Dichloroethane 1,2			0.005 mg/L		< 20 µg/L	Central nervous system disorders, and adverse lung, kidney, liver circulatory and gastrointestinal effects, cancer	Making chemicals involved in plastics, rubber and synthetic textile fibers, solvent for resins and fats, photography, photocopying, cosmetics, drugs, fumigant for grains and orchards
Dichloroethylene 1,1			0.014 mg/L		< 1 µg/L	Liver and kidney damage, as well as toxicity to the developing fetus, cancer	Making adhesives, synthetic fibers, refrigerants, food packaging and coating resins such as the saran types
Dichloromethane			0.05 mg/L		< 39.5 µg/L	Damage to the nervous system and to blood, liver damage, cancer	Paint remover, solvent and cleaning agent in a variety of industries, fumigant for strawberries and grains, to extract substances from foodstuffs
Ethylbenzene			0.0024		< 15 µg/L	Drowsiness, fatigue,	To make styrene, another

			mg/L			headache and mild eye and respiratory irritation, damage to the liver, kidneys, central nervous system and eyes	organic liquid used as a building block for many plastics, solvent for coatings, and in making rubber and plastic wrap
Monochlorobenzene			0.08 mg/L		< 6,400 µg/L	Anesthetic effects and impaired liver and kidney function, liver, kidney and central nervous system damage	Manufacture of other organic chemicals, dyestuffs and insecticides, solvent for adhesives, drugs, rubber, paints and dry-cleaning, and as a fiber-swelling agent in textile processing
Contaminant	**Recreational Guidelines**	**Recreational EPA Guidelines**	**Drinking Water Guidelines**	**Drinking Water NATO Guidelines**	**Environmental Concentration**	**Health Risks**	**Sources/Uses/ Potentially contaminated areas**
Tetrachloroethylene			0.03 mg/L		< 35 µg/L	Liver damage and cancer	Textile industry, and as a component of aerosol dry-cleaning products
Toluene			0.024 mg/L		< 100 µg/L	Minor nervous system disorders such as fatigue, nausea, weakness, confusion, spasms, tremors, impairment of speech, hearing, vision, memory, coordination, liver and kidney damage	To make benzene and urethane
Trichloroethylene			0.05 mg/L		< 200 µg/L	Liver problems and cancer	To remove grease from fabricated metal parts and some textiles
Trihalomethanes (total)			0.1 mg/L		< 4.5 µg/L	Liver, kidneys, central nervous systems, cancer	Disinfection byproduct
Vinyl chloride			0.002 mg/L		< 56 mg/L	Damage to the liver and nervous system, cancer	Manufacture of products in building and construction, automotive

							industry, electrical wire
Xylenes (total)			0.3 mg/L		< 5,385 µg/L	Disturbances of cognitive abilities, balance, and coordination, damage to the central nervous system	insulation and cables, piping, industrial and household equipment, medical supplies, and is depended upon heavily by the rubber, paper, and glass industries Solvent, in gasoline as part of the BTX component (benzene-toluene-xylene), to make phthalate plasticizers, polyester fiber, film and fabricated items
Polycyclic aromatic hydrocarbons							
Benzo(a) pyrene			0.00001 mg/L		< 1 ng/L	Red blood cell damage, leading to anemia, suppressed immune system, developmental and reproductive effects, cancer	Formed as a result of incomplete combustion of organic materials
Polychlorobiphenyls					< 500 ng/L	Acne-like eruptions and pigmentation of the skin, hearing and vision problems, spasms, irritation of nose, throat and gastrointestinal tract, changes in liver function, cancer	Used as hydraulic fluids, plasticizers, adhesives, fire retardants, way extenders, de-dusting agents, pesticide extenders, inks, lubricants, cutting oils, in heat transfer systems, carbonless reproducing paper
Toxins							
Cyanobacterial toxins			0.0015 mg/L			Liver damage, liver cancer, neurotoxicity	Produced by cyanobacteria
NBC agents							

BZ (incapacitants)				7 mg/L		Central nervous system	Chemical weapons
Lewisite (arsenic fraction)				80 mg/L		Irritant to skin and eyes	Chemical weapons
Sulfur mustard				140 mg/L		Irritation and burns of the skin, eyes, and respiratory tract, reproductive effects, and may cause cancer of the respiratory tract	Chemical weapons
Nerve agents				12 mg/L		Asphyxiation, blurred vision, drooling and convulsions	Chemical weapons
T-2 toxins				26 mg/L		Cancer	Produced by fungi, NBC agent

Contaminant	Recreational Guidelines	Recreational EPA Guidelines	Drinking Water Guidelines	Drinking Water NATO Guidelines	Environmental Concentration	Health Risks	Sources/Uses/ Potentially contaminated areas
Radiological							
Natural							
Lead-210			0.1 Bq/L			Increased risk of getting cancer	Nuclear weapon testing, uranium mining,
Radium-224			2 Bq/L			Increased risk of getting cancer	Nuclear power generation, industrial/medical
Radium-226			0.6 Bq/L		< 12.67 mBq/L	Increased risk of getting cancer	Uses of radioisotopes
Radium-228			0.5 Bq/L			Increased risk of getting cancer	
Thorium-228			2 Bq/L			Increased risk of getting cancer	
Thorium-230			0.4 Bq/L			Increased risk of getting cancer	
Thorium-232			0.1 Bq/L			Increased risk of getting cancer	
Thorium-234			20 Bq/L			Increased risk of getting cancer	
Uranium-234			4 Bq/L			Increased risk of getting cancer	
Uranium-235			4 Bq/L			Increased risk of getting cancer	
Uranium-238			4 Bq/L			Increased risk of getting cancer	
Artificial							
Cesium-134			7 Bq/L			Increased risk of getting cancer	
Cesium-137			10 Bq/L		< 13.69 mBq/L	Increased risk of getting cancer	
Iodine-125			10 Bq/L			Increased risk of getting cancer	
Iodine-131			6 Bq/L			Increased risk of getting cancer	

Molybdenum-99			70 Bq/L			Increased risk of getting cancer
Strontium-90			5 Bq/L			Increased risk of getting cancer
Tritium			7000 Bq/L		< 12.24 mBq/L	Increased risk of getting cancer
Total radiological compounds				300000 Bq/L		Increased risk of getting cancer

Annex B List of web sites

Environment Canada's National Pollutant Release Inventory:
http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm

United Nations Environment Program – GEMS/Water:
http://www.gemswater.org/freshwater_assessments/index-e.html

US EPA - Ground water and drinking water:
http://www.epa.gov/safewater/hfacts.html

US EPA – Water Quality Standards Database:
http://www.epa.gov/wqsdatabase/wqsreports.html

US EPA – Beach standards, monitoring and notification:
http://www.epa.gov/waterscience/beaches/

The EXtension TOXicology NETwork:
http://extoxnet.orst.edu/ghindex.html

IPCS - Environmental Health Criteria Monographs:
http://www.inchem.org/pages/ehc.html

Canadian Council of Ministers of the Environment:
http://www.ccme.ca/index.html

Risks databases:
http://www.riskworld.com/websites/webfiles/ws6aa003.htm

National Water Research Institute – Environment Canada:
http://www.nwri.ca/nwri-e.html

Freshwater web site – Environment Canada:
http://www.ec.gc.ca/water/e_main.html

The green lane – Environment Canada:
http://www.ec.gc.ca/envhome.html

Canadian Water Quality Guidelines:
http://www.ccme.ca/assets/pdf/e1_06.pdf

Ontario Ministry of the Environment – Water:
http://www.ene.gov.on.ca/water.htm

Great lakes beach cast:
http://www.great-lakes.net/beachcast/index.html

List of symbols/abbreviations/acronyms/initialisms

CF	Canadian Forces
FC	Forces Canadiennes
HHG	Health Hazards Group
DRDC	Defence Research & Development Canada
RDDC	Recherche et Développement pour la Défense Canada
PAHs	Polyaromatic hydrocarbons
VOCs	Volatile organic compounds
PCB	Polychlorinated biphenyl
NATO	North Atlantic Treaty Organization
OTAN	Organisation du Traité de l'Atlantique Nord
MCW	Moderately contaminated water
HCW	Highly contaminated water
NBC	Nuclear, biological and chemical
US EPA	United States Environmental Protection Agency
DFHP	Directorate Force Health Protection
D Dive S	Directorate Dive Safety
WHO	World Health Organization
NOAA	National Oceanographic and Atmospheric Administration
US Navy	United States Navy
CCREM	Canadian Council of Resource and Environment Ministers
AFRI	Acute Febrile Respiratory Illness
DDT	Dichloro Diphenyl Trichloroethane
TBT	Tributyltin
IPCS	International Program on Chemical Safety

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Diving in Contaminated Water − Health Risk Matrix (U)
Plongée en Eau Contaminée − Matrice de Risques

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Bernadette Quémerais

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(U) Water contamination can pose a serious health risk to divers of the Canadian Forces (CF) required to dive in many different environments. D Dive S tasked DRDC to develop a health risk matrix in order to help the decision makers to evaluate the risks associated with water contamination in a particular area. This report contains information about water contamination and recommendations on contamination assessment. A matrix was developed using Canadian Environmental Quality Guidelines (Canadian Council of Resource and Environment Ministers, 1998) as well as North Atlantic Treaty Organization (NATO) guidelines (NATO, 2002). The matrix also contains information on maximum environmental levels, health risks and toxicity, sources, uses and potentially contaminated areas. As the matrix is a tool for divers, few recommendations are given for its use. A list of useful web sites is also given.

14. KEYWORDS, DESCRIPTORS or IDENTIFIERS (Technically meaningful terms or short phrases that characterize a document and could be helpful in cataloguing the document. They should be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location may also be included. If possible keywords should be selected from a published thesaurus, e.g. Thesaurus of Engineering and Scientific Terms (TEST) and that thesaurus identified. If it is not possible to select indexing terms which are Unclassified, the classification of each should be indicated as with the title.)

(U) contaminated water, water, diving

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